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AMOUNT, DISTRIBUTION, AND SEASONAL TREND OF CERTAIN ORGANIC RESERVES IN THE ROOT SYSTEM OF FIELD BINDWEED, CONVOLVULUS ARVENSIS L.

AN EXPANSION OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE BIOLOGICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF BOTANY

1939

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JOHN C. FRAZIER

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AMOUNT, DISTRIBUTION, AND SEASONAL TREND OF CERTAIN ORGANIC RESERVES IN THE ROOT SYSTEM OF FIELD BINDWEED, *CONVOLVULUS ARVENSIS* L.[1]

JOHN C. FRAZIER

(WITH SIX FIGURES)

Introduction

Field bindweed, *Convolvulus arvensis,* is recognized as one of the more serious of the noxious weeds in the central United States. Four of the five federal projects established to study control measures for this plant are located in this area (Hays, Kansas; York, Nebraska; Cherokee, Iowa; and Lamberton, Minnesota).

During the past two or three decades practical means of control have been studied at various places. Empirical methods, however, have not resulted in satisfactory control and there has been a trend to include in a general research program studies dealing specifically with the physiology of the plant, especially studies of its food reserves. The persistent nature of noxious perennial weeds is intimately related to the organic reserves stored in their roots. The study herein reported deals particularly with the organic reserves of the root system when undisturbed by cultivation.

A study of the nature of the root system (**10**) showed the advisability of dividing it into a number of portions for detailed studies of their organic reserves. Analytical determinations were made upon 7 of these portions found in the upper 3 feet of soil, to learn the amount and relative distribution of certain of the organic reserves during the growing season.

ENVIRONMENTAL FACTORS

The environmental factors of soil type, precipitation, and air temperatures under which this study was made are given in detail by FRAZIER (**10**).

Briefly, it may be stated that the soil was a deep Geary silt loam, no layer of which impeded root development. The rainfall the preceding year was 24.54 inches which was 74 per cent. of normal; while during the first 10 months of 1937 the precipitation was 20.88 inches, which was 69 per cent. of normal for this period. The air temperatures the preceding year showed great extremes. On 60 days, temperatures of 100° F. or higher were reached (the average number is 15). The summer of 1937 was less extreme with temperatures of 100° being attained on only 38 days. The growth of bindweed was definitely terminated on November 17 on which date the temperature fell to 12° F.

Materials and methods

PHYSICAL METHODS

The roots used in this study were obtained by a modification of the trench-

[1] Contribution no. 419 from the Department of Botany, Kansas Agricultural Experiment Station.

ing method developed by WEAVER (**25**). This involved the use of a hand pick and an ice pick to expose and free the underground parts after suitable trenches had been made by excavating operations.

Roots secured for analytical studies were taken twice a month—the first and fifteenth—from April 1, 1937, to October 1, 1937, with a fourteenth and final sampling on November 1, 1937. All roots were taken from the one area of well-established, undisturbed bindweed, which was subjected to normal root competition by a uniform, but sparse stand of other weeds. There was scarcely any competition for light as the bindweed shoots twined over the other weeds.

The material was divided into the 7 portions of the root system as collected and kept in moist cloths until it was taken to the laboratory. There it was washed free of soil particles, blotted dry with cloths, cut in pieces approximately one-fourth of an inch in length, and placed in individual wire trays.

The root material was killed in an electric oven at a temperature of 95° C. This ordinarily required from 20 to 30 minutes. It was then dried at 70° C. in an electric oven for at least 14 hours.

The material was ground in a food grinder and then reduced to 60-mesh size with a mortar and pestle. It was stored in sealed glass containers, then redried at 100° C. for 14 hours before samples were taken for analysis.

One hundred lineal feet of each of the 3 portions into which the vertical roots were divided and one hundred lineal feet of the lateral roots of comparable plants growing in the same area of land were excavated and weighed in late July, 1939.

CHEMICAL METHODS

The following fractions were determined in each of the 7 divisions into which the root system was divided: total nitrogen, protein nitrogen, nonprotein nitrogen, reducing sugars, total sugars, the starch-dextrin fraction, and the readily available carbohydrate fraction. All results are the averages of closely-agreeing duplicate analyses.

TOTAL NITROGEN.—The diphenylamine test (**13**) showed the material to be free of nitrates which agrees with the findings of BAKKE *et al.* (**3**) and the Kjeldahl-Gunning-Arnold method (**2**) as modified by MILLER (**14**) was used to determine the total nitrogen in 1-gram samples.

PROTEIN NITROGEN.—This fraction as determined is considered to include the unextracted nitrogen plus that coagulated by specific treatment and is the method that has been employed in this laboratory (**14**).

NONPROTEIN NITROGEN.—This was obtained by subtracting the percentage of the protein nitrogen from the percentage of total nitrogen.

The reducing sugars, total sugars, and the starch-dextrin fraction were determined from a 3-gram sample, using methods adapted from those employed in this laboratory (**14**). The sample was extracted with 100 ml. of 80 per cent. alcohol for 2 hours in a 70° C. bath, filtered, the filtrate used for sugar, and the residue for starch-dextrin determinations.

REDUCING AND TOTAL SUGARS.—The filtrate was freed of alcohol by evaporation and the resulting water solution was cleared by the use of neutral lead acetate, brought to volume, deleaded with sodium oxalate, the lead oxalate precipitate allowed to settle, and a 50-ml. aliquot pipetted off for reducing sugar determinations. One hundred milliliters of the remaining aqueous solution were pipetted into a 250-ml. volumetric flask, acidified with 2.5 per cent. hydrochloric acid and hydrolyzed for 5 minutes at 70° C., as described by LOOMIS and SHULL (**13**), nearly neutralized with 20 per cent. sodium hydroxide, made to volume and a 50-ml. aliquot taken for total sugar determinations.

STARCH-DEXTRIN FRACTION.—The residue of the original separation was transferred to a beaker by means of hot water, made to approximately 100 ml. volume and boiled for 2 minutes to gelatinize the starch. After cooling, 10 ml. of fresh filtered saliva and 1 ml. of toluene were added and the contents of the beaker stirred thoroughly.

The beaker, covered with a watch glass, was placed in an electric oven at 38–40° C. for 14 hours, checked as being starch-free with iodine, filtered into a volumetric flask, washed with hot water, cooled, cleared with neutral lead acetate, made to volume, deleaded with sodium oxalate, the lead oxalate allowed to settle, and a 200-ml. aliquot pipetted into an Erlenmeyer flask, acidified with 2.5 per cent. hydrochloric acid, refluxed for 3 hours, nearly neutralized with 40 per cent. sodium hydroxide, brought to volume in a 250-ml. volumetric flask, and a 50-ml. aliquot taken for the starch-dextrin fraction determination.

All carbohydrate fractions were determined gravimetrically by weighing the cuprous oxide directly. The conditions of MUNSON and WALKER (**15**) were followed for reduction. The d-glucose equivalent was obtained from the MUNSON and WALKER tables.

READILY AVAILABLE CARBOHYDRATE FRACTION.—This composite fraction was computed by adding the percentage of total sugars to the percentage of the starch-dextrin fraction.

All results were obtained in percentage and in grams per 100 lineal feet for each of the reserve food fractions in each of the 7 portions into which the plants were arbitrarily divided. The weight in grams per 100 lineal feet for any reserve food fraction was obtained by multiplying the weight of 100 lineal feet of the plant portion by the percentage of the reserve food fraction in that portion.

Experimental studies

NATURE OF THE PLANT

FRAZIER (**10**) has described in some detail the gross nature of the undisturbed bindweed plant grown from seed. In summary, it was found that the undisturbed root system may be divided into three natural portions: (1) primary vertical root, which is the original root of the plant developing from the radicle of the seed; (2) permanent lateral roots, those lateral roots

that develop more extensively and persist as permanent parts of the root system; and (3) secondary vertical roots which are the downward extensions from the permanent lateral roots after the latter have made 10 to 30 inches of horizontal growth.

In this study all permanent lateral roots of whatever order (10) are considered together, and likewise all secondary vertical roots are considered collectively, regardless of their order of development. The two types of vertical roots were each divided into the first-, second-, and third-foot divisions or portions. These 6 divisions and the lateral-root division constitute the 7 portions of the plant into which it was arbitrarily divided for the purpose of determining the distribution and trend of organic reserves during the growing season, April 1 through November 1. The so-termed "first foot" of the secondary vertical roots was considered to begin where the slender lateral root suddenly enlarged markedly. This "first foot" was the first 12 inches of root beyond that point. Ordinarily this portion was entirely contained in the first foot of the soil. All the material designated as lateral roots came from the first-foot soil level.

Organic reserves of the plant

Percentage basis.—These results are reported as the percentage of the reserve food fraction in the dry material of the root portion. It was not possible to report them as percentages of the total dry weight of the entire plant since under field conditions complete plants could not be secured in sufficient numbers.

It is recognized that percentages may not give a true picture of the changes that are occurring in the actual amounts of organic reserves in the plant. An increase in the actual amount of one fraction may bring about an "apparent" decrease in another fraction, when reported on a percentage basis, despite the fact that there has been no actual decrease in the latter fraction. Admittedly the changes from protein nitrogen to the nonprotein nitrogen fraction and vice versa, and from sugars to the starch-dextrin fraction and vice versa, will show apparent errors in these fractions. It is contended, however, that the total nitrogen and the total readily available carbohydrate fractions are fairly reliable indices, as such shifts would be occurring within these fractions and would not materially change their values.

Nitrogen fractions.—*The primary vertical roots.*—In figure 1[2] the data are given for the total nitrogen, protein nitrogen, and nonprotein nitrogen fractions, expressed in percentage on a dry weight basis, for the 3 portions of the primary vertical roots. There is a definite decrease from April 15 to June 15, the decrease being more marked in some portions. There is less protein nitrogen relative to nonprotein nitrogen in the second, and still less in the third foot portion. The total-nitrogen and protein-nitrogen fractions reached their seasonal low points on August 15 in the second and third foot levels.

[2] The data, other than tables I and II, on which the graphs of this paper are based, are on file at the Kansas Agricultural Experiment Station, available upon request.

The secondary vertical roots.—In figure 2 the data are given for the total nitrogen, protein nitrogen and nonprotein nitrogen, expressed in percentage on a dry-weight basis for the secondary vertical roots. There was the same early season decrease following April 15, as in the primary vertical roots. The low point in the total nitrogen and protein nitrogen fractions of these

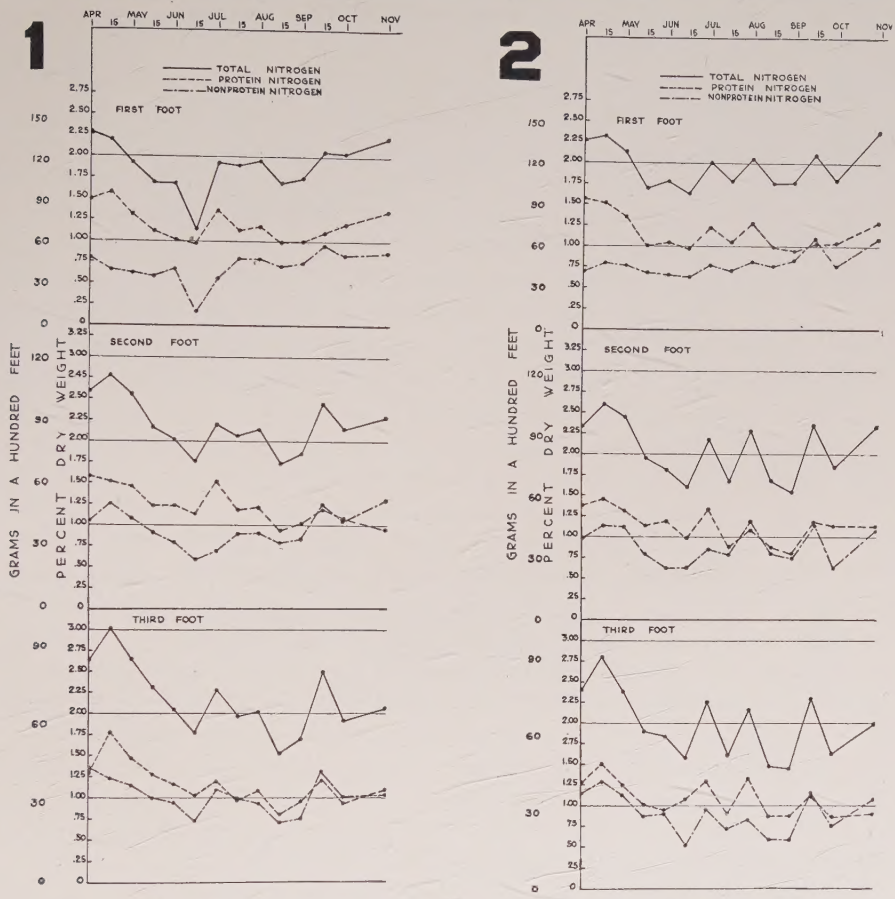

FIG. 1. The total nitrogen, protein nitrogen, and nonprotein nitrogen fractions in percentage on a dry weight basis and in grams per 100 lineal feet in the first, second, and third foot portions of the primary vertical root.

FIG. 2. The total nitrogen, protein nitrogen, and nonprotein nitrogen fractions in percentage on a dry weight basis and in grams per 100 lineal feet in the first, second, and third foot portions of the secondary vertical root.

roots centered, however, about September 1, except for the former in the surface foot. The trends after June 15 show more marked variations than those of the same fraction in the corresponding portion of the primary vertical root, but the general range of percentages does not differ markedly.

The lateral roots.—Figure 3 gives the data for the 3 nitrogen fractions in percentage of dry weight for the lateral roots. The early season decline is quite marked, especially in the total nitrogen fraction, due to the increase

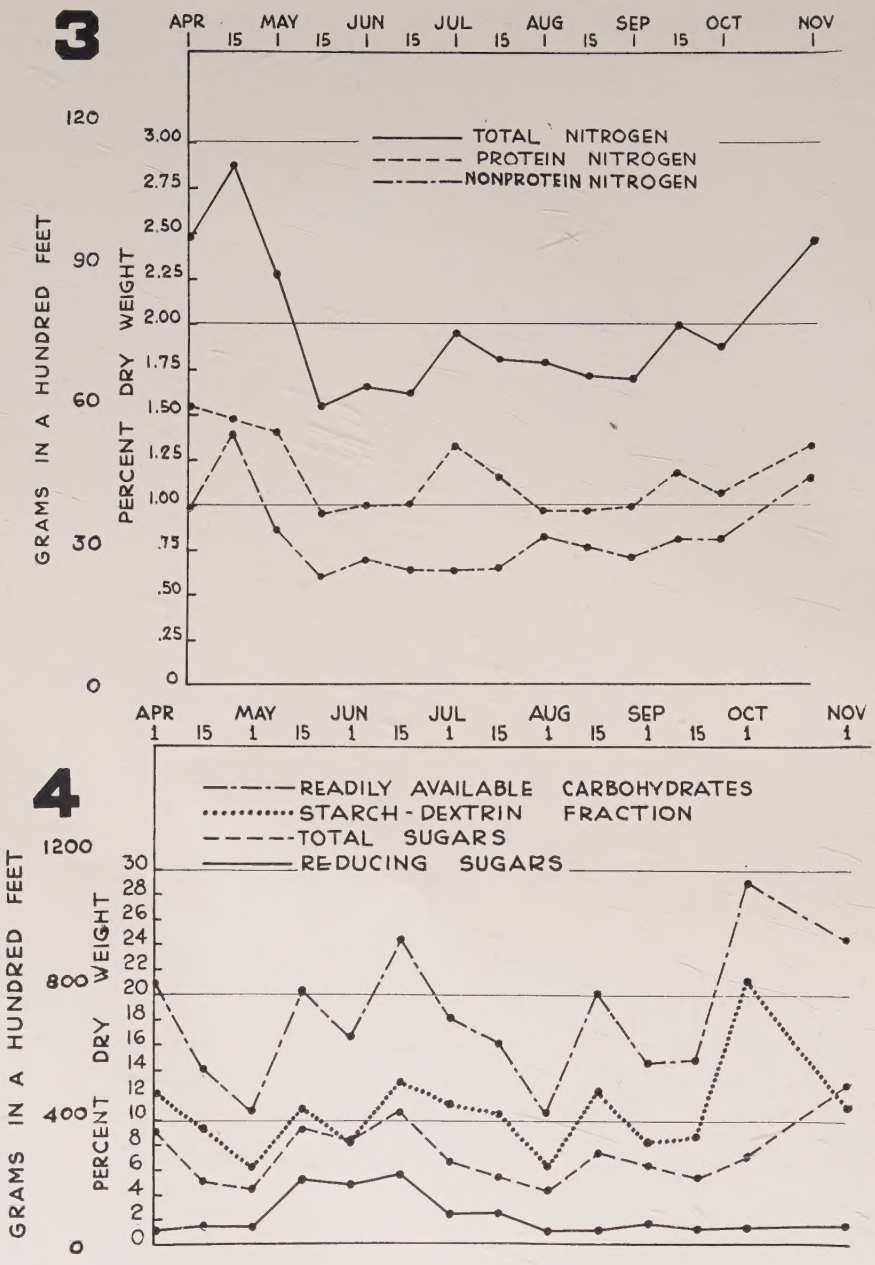

FIG. 3. The total nitrogen, protein nitrogen, and nonprotein nitrogen fractions in percentage on a dry weight basis and in grams per 100 lineal feet of the lateral root.

FIG. 4. The reducing sugars, total sugars, starch-dextrin fraction, and readily available carbohydrates in percentage on a dry weight basis and in grams per 100 lineal feet of the lateral root.

between April 1 and 15. Lows are found in the total-nitrogen and protein-nitrogen fractions in the months of May 15 to June 15 and August 1 to September 1. The general range of percentages of the 3 fractions is much the same as in the two types of vertical roots if the extremely low point of total proteins on June 15 in the primary vertical roots and the high point of this fraction on April 15 in the lateral roots are not allowed to bias the picture.

CARBOHYDRATE FRACTIONS.—*The primary vertical roots.*—Data are given in tables I and II for total sugars and the starch-dextrin fraction and in figure 5 for reducing sugars, total sugars, the starch-dextrin fraction, and the readily available carbohydrate fraction for the primary vertical roots.

The reducing sugars differed somewhat in their seasonal trend in the 3 portions. The early season low was from April 15 to May 15 in the first, from April 15 to May 1 in the second, and on April 1 in the third foot. There was a decrease in the first foot portion after July 15.

The total sugars showed an early season decrease in all portions. The seasonal low was reached by this fraction on May 15 in the first, on July 1 in the second, and on April 15 in the third foot portion. High levels were attained on June 15 and November 1 in the first, on June 1, September 15, and October 1 in the second, and on June 15 and August 15 in the third foot portion.

The starch-dextrin fraction reached a low point on May 1 in all three foot portions. This reserve fraction in the first foot portion was less than the total sugars on May 1 and June 15. The high points for the starch-dextrin fraction was on October 1 for the first, August 15 and October 1 for the second, and September 1 for the third foot portion. This fraction attained progressively higher percentages in the second and third foot portions.

The readily available carbohydrate fraction had the same general trend as the starch-dextrin fraction except between May 1 and July 1 in the first foot portion. It also attained progressively higher percentages in the second and third foot portions.

The secondary vertical roots.—Data are given in tables I and II for total sugars and the starch-dextrin fraction and in figure 6 for reducing sugars, total sugars, the starch-dextrin fraction, and the readily available carbohydrate fraction for the secondary vertical roots.

The reducing sugars differed in their trends from those in the corresponding portions of the primary vertical root. This fraction ran slightly higher in these roots than in comparable portions of the primary vertical root.

The total sugars reached low points on April 15, June 1, August 1, and October 1 in the first, on May 15 and October 1 in the second, and on May 15 in the third foot portion. High levels were attained on May 1, June 15, the month of August 15 to September 15, and November 1 in the first foot (the peak on November 1), on September 1 in the second, and on June 15 in the third foot levels. If the extremely low point reached in the first foot of the

TABLE I

TOTAL SUGARS IN PERCENTAGE AND IN GRAMS PER HUNDRED LINEAL FEET. MANHATTAN, KANSAS, 1937

DATE	PRIMARY VERTICAL ROOT						SECONDARY VERTICAL ROOT						LATERAL ROOT	
	1ST FOOT		2D FOOT		3D FOOT		1ST FOOT		2D FOOT		3D FOOT			
	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*
April 1	6.04	374	8.86	360	8.86	286	8.08	500	8.72	354	9.92	320	9.12	346
April 15	4.75	294	6.42	261	5.17	167	5.75	356	7.83	318	8.46	273	5.00	190
May 1	5.33	330	5.37	218	7.17	232	8.12	503	6.45	262	11.25	363	4.29	163
May 15	1.96	121	5.83	237	8.12	262	7.38	457	6.01	244	5.21	168	9.23	350
June 1	6.62	410	9.54	387	9.92	320	5.33	330	8.21	333	12.66	409	8.23	312
June 15	8.42	521	7.25	294	11.50	371	8.58	531	8.21	333	13.20	426	10.96	415
July 1	3.31	205	4.29	174	10.00	323	6.20	384	8.71	354	9.54	308	6.98	265
July 15	6.96	431	8.42	342	9.79	316	6.79	420	10.76	437	11.33	366	5.96	226
August 1	7.08	438	7.38	300	10.08	326	5.04	312	8.33	338	8.80	284	4.04	153
August 15	6.79	420	9.13	371	12.63	408	8.88	550	9.13	371	9.08	293	7.78	295
Sept. 1	7.29	451	8.29	337	9.29	300	8.45	523	12.04	489	11.58	374	6.41	243
Sept. 15	7.21	446	9.46	384	7.54	244	8.88	550	9.13	371	9.59	310	5.71	216
Oct. 1	5.06	313	9.87	401	8.50	275	5.46	338	5.69	231	9.17	296	7.54	286
Nov. 1	9.54	591	9.17	372	8.13	263	9.58	593	9.91	402	10.50	339	13.21	501

TABLE II

STARCH-DEXTRIN FRACTION IN PERCENTAGE AND IN GRAMS PER HUNDRED LINEAL FEET. MANHATTAN, KANSAS, 1937

DATE	PRIMARY VERTICAL ROOT						SECONDARY VERTICAL ROOT						LATERAL ROOT	
	1ST FOOT		2D FOOT		3D FOOT		1ST FOOT		2D FOOT		3D FOOT			
	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*	%	*gm.*
April 1	5.45	337	10.85	441	23.99	775	11.05	684	20.11	816	25.28	817	12.17	461
April 15	4.98	308	12.58	511	14.29	462	7.21	446	13.96	567	17.63	569	9.05	343
May 1	1.75	108	7.81	317	11.42	369	5.60	347	11.04	448	13.08	422	6.50	246
May 15	4.50	279	9.94	404	13.79	445	8.20	508	15.10	613	18.56	599	11.38	431
June 1	7.84	485	14.12	573	18.35	593	9.33	578	16.42	667	22.52	727	8.16	309
June 15	6.02	373	9.11	370	14.85	480	15.91	985	17.73	720	26.88	868	13.75	521
July 1	6.88	426	13.28	539	17.04	550	5.28	327	15.42	626	11.66	377	11.79	447
July 15	11.44	708	18.83	765	21.60	698	12.06	747	22.79	925	26.19	846	10.75	407
August 1	11.58	717	21.39	868	26.12	844	8.04	498	19.37	786	22.17	716	6.51	247
August 15	12.10	749	22.62	918	27.58	891	14.06	870	30.77	1249	38.27	1236	12.69	481
Sept. 1	7.92	490	19.83	805	31.95	1032	14.06	870	19.25	782	33.52	1083	8.05	305
Sept. 15	8.98	556	17.50	711	22.36	722	13.85	857	19.48	791	26.61	860	8.92	338
Oct. 1	15.15	938	22.50	914	27.56	890	21.42	1326	30.68	1246	34.93	1128	21.56	817
Nov. 1	8.92	552	20.23	821	25.96	839	12.37	766	24.55	997	31.10	1005	11.08	420

primary vertical root is overlooked, however, the range of percentages is similar in the two types of vertical roots.

The starch-dextrin fraction trends were downward in all portions until May 1. In the first foot portion, the starch-dextrin fraction was less than the total sugar fraction on May 1 and July 1. The general trends were similar to those of this fraction in corresponding portions of the primary vertical root, except that marked low points were reached in the first and third foot portions on July 1. The fraction, however, ran 4 to 6 per cent. higher

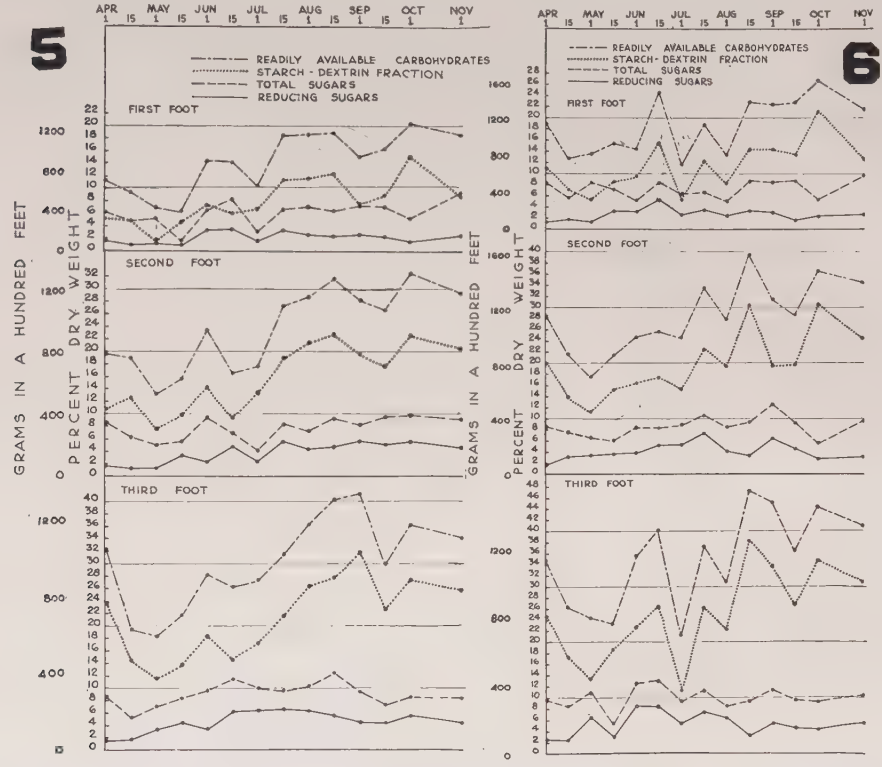

FIG. 5. The reducing sugars, total sugars, starch-dextrin fraction, and readily available carbohydrates in percentage on a dry weight basis and in grams per 100 lineal feet in the first, second, and third foot portions of the primary vertical root.

FIG. 6. The reducing sugars, total sugars, starch-dextrin fraction, and readily available carbohydrates in percentage on a dry weight basis and in grams per 100 lineal feet in the first, second, and third foot portions of the secondary vertical root.

in many instances than in the corresponding portion of the primary root.

The readily available carbohydrate fraction showed the same general trends as the starch-dextrin fraction in this root. This fraction ran 6 to 8 per cent. higher in many instances than corresponding portions of the primary vertical root.

The lateral roots.—Data are given in tables I and II for total sugars and the starch-dextrin fraction, and in figure 4 for reducing sugars, total

sugars, the starch-dextrin fraction, and the readily available carbohydrate fraction for the lateral roots.

The low point of reducing sugars occurred at the start of the study on April 1 and a second low interval existed from August 1 to August 15. The peak was attained on June 15. The general trend was similar as for this fraction in the first foot portion of the two types of vertical roots.

The total sugars reached low points on May 1 and on August 1 and attained high levels on June 15 and November 1. The general trend differed somewhat from those of this fraction in the first foot level of the vertical roots.

The starch-dextrin fraction dropped to low points on May 1 and on August 1. High points were reached on June 15 and August 15, but the peak was reached on October 1. On June 1 and November 1 this fraction was slightly less than the total sugar fraction.

The trend of the total readily available carbohydrate fraction practically paralleled that of the starch-dextrin fraction for this root. A high point was reached on June 15, with the seasonal peak being attained on October 1. The percentages of this fraction, as in the starch-dextrin fraction, more closely approximated those in the first foot of the secondary than in the first foot of the primary vertical roots.

Basis of actual amount.—The story of any reserve food fraction expressed on a percentage basis is confusing in that the percentage ordinarily increases with depth while the actual amount ordinarily decreases. The findings of Bakke *et al.* (**3**) show these trends.

In order to give the results of this study in terms of the actual amounts of each of the individual reserve food fractions in each of the 7 portions into which the plant was arbitrarily divided, the weight of 100 lineal feet of each of the 3 portions into which the vertical roots were divided and 100 lineal feet of the lateral roots was obtained by excavating representative roots of comparable plants and weighing them. These weights were as follows:

Weight of 100 lineal feet

Vertical root	
1st foot portion	61.9 gm.
2d " "	40.6 "
3d " "	32.3 "
Lateral root	37.9 "

The weight of the individual root portion was then multiplied by the percentage of the reserve food fraction in that portion to give the actual weight of that reserve fraction in 100 feet of that portion. These data have been computed and they show that the picture of reserves from the standpoint of actual amounts is markedly different from that constructed on a percentage basis. A specific case involving the first and third foot portions of the primary vertical root for August 1 illustrates this point. On a per-

centage basis, the first foot had 18.66 and the third foot 36.20 per cent. of the total readily available carbohydrate fraction, while on the basis of the actual amount of this reserve fraction, the first foot had 1,155 grams as compared with 1,169 grams in the third foot. Hence, with almost twice the percentage of this reserve fraction, the third foot had but little more of the fraction.

Nitrogen fractions.—These computed data are given in graphic form. Figures 1, 2, and 3, inclusive, give total nitrogen, protein nitrogen, and nonprotein nitrogen fractions in the primary vertical roots, the secondary vertical roots, and the lateral roots in grams per 100 lineal feet.

Carbohydrate fractions.—The computed data for total sugars and the starch-dextrin fraction are given in both tabular (tables I and II) and graphic form (figs. 4, 5, and 6), and in graphic form only for reducing sugars and the readily available carbohydrate fraction in the lateral, the primary vertical, and the secondary vertical roots, respectively.

It is obvious because of the method of calculation that the trend of the data reporting the actual amount of a reserve food fraction in grams per 100 lineal feet of a root portion will be the same as that of those reporting the percentage of this reserve food fraction in the same root portion.

Statistical treatment of differences between comparable portions of vertical roots

The seasonal trend of the various carbohydrate and nitrogen fractions was essentially the same for the primary and secondary vertical roots, hence comparable foot portions of these roots were paired by sampling dates and the differences of these various fractions in the comparable portions treated statistically, using the t test, to ascertain if the differences were statistically significant and, if so, to what degree (**17**). The value of t was used to determine the probability (P) from the tables for P values given by Fisher and Yates (**9**). These values are given in table III.

These P values showed that the differences observed between comparable portions of the two types of vertical roots were statistically significant in many instances. The differences in the total nitrogen fraction in the second and third foot portions, the protein nitrogen in the second foot portion, and the nonprotein fraction in the first foot portion were at least significant. The reducing and total sugars were at least significantly different in the first foot portion, while the starch-dextrin and readily available carbohydrate portions were at least significantly greater in the secondary vertical roots in all three foot levels.

It would appear that the statistical significance of the differences warrants consideration. Under ordinary conditions of growth, however, the secondary vertical roots outnumber the primary ones from two to many times, which may mean that root samples taken from undisturbed bindweed are predominantly of the one type. Then, too, the effect of control procedures, such as cultivation, on these differences is not known.

TABLE III

THE t VALUE, PROBABILITY, AND DEGREES OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN THE VARIOUS ORGANIC RESERVE FRACTIONS FOUND IN COMPARABLE FOOT PORTIONS OF THE TWO TYPES OF VERTICAL ROOTS PAIRED BY SAMPLING DATES

FOOT INTERVAL	AVERAGE OF RESERVE FRACTION FROM 14 DATES OF SAMPLING		t VALUE (13 df.)	P (PROBABILITY)	SIGNIFICANCE
	VERTICAL ROOT				
	PRIMARY	SECONDARY			
	NITROGEN FRACTIONS				
	Total nitrogen				
	%	%			
1	26.54	27.51	1.516	0.16	n.s.
2	30.75	28.62	3.656	0.005	†
3	30.43	27.80	4.893	<0.001	‡
	Protein nitrogen				
1	16.84	16.38	1.443	0.18	n.s.
2	17.29	15.91	3.091	<0.01	†
3	16.24	15.25	1.720	0.11	n.s.
	Nonprotein nitrogen				
1	9.70	11.13	2.484	0.03	*
2	13.46	12.71	1.288	0.22	n.s.
3	14.19	12.55	0.439	0.67	n.s.
	CARBOHYDRATE FRACTIONS				
	Reducing sugars				
1	31.68	37.67	19.810	<<0.001	‡
2	53.12	57.96	0.789	0.46	n.s.
3	63.83	74.29	1.399	0.19	n.s.
	Total sugars				
1	86.36	102.52	2.233	0.045	*
2	109.28	119.13	1.246	0.24	n.s.
3	126.70	140.29	1.605	0.14	n.s.
	STARCH-DEXTRIN FRACTION				
1	113.51	158.44	3.504	0.006	†
2	220.59	276.67	4.275	<0.001	‡
3	296.86	348.40	2.921	0.012	*
	READILY AVAILABLE CARBOHYDRATES				
1	199.87	260.96	3.858	0.004	†
2	329.87	395.80	5.751	<0.001	‡
3	423.56	488.69	10.689	<<0.001	‡

n.s. Nonsignificant.
* Significant at 5% level.
† Significant at 1% level.
‡ Significant at 0.1% level.
< Less than.

Discussion

Comparatively few specific data have been gathered on the food reserves of weeds. BARR (5) has summarized the investigations in this field to 1936.

The papers by ARNY (**1**) and WELTON, MORRIS and HARTZLER (**26**) are similar to the study reported in this paper in that they follow the nitrogen and carbohydrate fractions in the roots of perennial weeds, other than bindweed, through the growing season, but the work was not done on material obtained from definite foot intervals of the soil.

Until recently food reserve studies on bindweed have been of a general nature. BARR (**5**) published the first rather complete analytical study of bindweed reserves in 1936.

It is the intention here to point out certain pertinent findings and viewpoints which may be of value in relating the results reported in this paper to the problem of food reserves in perennial weeds, particularly field bindweed, rather than to compare these with the specific results of other workers.

NITROGEN FRACTIONS

ARNY (**1**) states that while nitrogen reserves are present in relatively small amounts in perennial weeds they are of great importance in the metabolism of the plant, particularly at the time of rapid tissue building in the wave of spring growth. Recent studies by TIMMONS (**19, 20, 21, 22, 23**), EVANS (**8**), BARR (**6**) and BAKKE *et al.* (**3**) indicate that the trend of total nitrogen reserves is independent of the trends shown by the various carbohydrate fractions; that the variation of the nitrogen fractions during the season is low; and that the trend of the total nitrogen fraction has little value as an index to the regenerative power of the plant. BAKKE *et al.* (**3**) state that their work indicates that nitrogen depletion, unlike carbohydrate depletion, was not directly affected by chlorate treatment.

CARBOHYDRATE FRACTIONS

LATSHAW and ZAHNLEY (**12**) made observations in 1927 on the starch reserves of bindweed, and CRAFTS and KENNEDY (**7**) stated in 1930 that the persistent vegetative activity of the plant is made possible by the storage of relatively large quantities of starch in the root system. BARR (**5**) published in 1936 the first detailed study of the carbohydrate reserves of the bindweed plant. This study, however, was on material obtained at one sampling date, *viz.*, August 5, 1935. Extensive work has been done on the trend of the carbohydrate fractions in undisturbed bindweed by the following workers on the federal bindweed project: BAKKE (**4**) at Hawarden and Cherokee, Iowa; EVANS (**8**) at York, Nebraska; SEELY (**16**) at Genesee, Idaho; STAHLER (**18**) at Lamberton, Minnesota; and TIMMONS (**23, 24**) at Hays, Kansas. A summarized report[3] of their work indicates that the computed fraction, the readily available carbohydrate fraction, has the same general trend at the 5 stations if the time of the start of spring growth and the subsequent stages of growth are taken into consideration. Consisting as it does of the total sugars and the starch-dextrin fraction, this computed

[3] Progress report of cooperative weed investigations. U. S. Dept. Agr., B. P. I., Washington, D. C. 1939. Mimeographed.

fraction was found by these investigators to be the most reliable index of the food reserves of the plant. BAKKE *et al.* (**3**) state that the reserves of the bindweed roots consist largely of sucrose and a dextrin-like compound or group of compounds. In the study reported herein these substances are included in the fraction designated as the readily available carbohydrates. BARR (**6**) gives the trends for the carbohydrate fraction in undisturbed bindweed for 3 years' investigations in Colorado. The trends for the starch-dextrin fraction and total sugar fraction ran quite similar to those reported in this paper. There was a difference in the reducing sugar trend, however. The total sugar percentages were much higher than those reported in this paper or by TIMMONS (**19, 20, 21, 22**).

Most of these analytical studies were on bindweed root material taken in the 0- to 12-inch or the 6- to 18-inch soil layer with certain exceptions such as: TIMMONS (**21, 22**) included five periods of sampling at what he termed "critical points in the seasonal curve for food reserves," taking samples from the 6- to 18-inch, 18- to 30-inch, and 30- to 48-inch soil layers; KIESSELBACH *et al.* (**11**) made "fodder" analyses of roots taken to a depth of 4 feet; BAKKE *et al.* (**3**) analyzed samples taken to a depth of 17 feet in 1936 and to a depth of 8 feet in 1937 as well as samples used in routine studies on the 0- to 12 and 12- to 36-inch soil layers. The study reported herein is believed to be the first in which detailed analyses were made on undisturbed bindweed roots from the first, second, and third foot soil levels throughout the growing season.

Summary

1. For the purpose of studying the distribution and seasonal trend of the various organic reserves in the roots during the growing season the root system was arbitrarily divided into the permanent lateral roots and the two types of vertical roots. The two types of vertical roots were each divided into the first, second, and third foot portions, which with the lateral roots gave a total of seven portions. Only roots of well-established, undisturbed plants were used, subject to but little competition from a sparse but uniform stand of other weeds.

2. The percentages of total nitrogen and protein nitrogen fractions in the seven portions of the bindweed root system at fourteen periods of sampling—April 1 to November 1, inclusive—were determined and reported.

3. A fraction obtained by subtracting the protein nitrogen fraction from the total nitrogen fraction was computed and reported. It is designated the nonprotein nitrogen fraction.

4. The general trend of the nitrogen fractions in practically all portions of the plant showed an early season rise to April 15, followed by a decline to a low point sometime during the interval, May 15 to June 15. Marked fluctuations occurred following this interval in many of the portions, succeeded by a second low interval, August 15 to September 1. In certain instances this was the low point of the season of the reserve fraction in that root portion. Additional fluctuations followed, which included a rise on

September 15 followed by a decline and then a rise on November 1. The general range of percentages was similar in the corresponding portions of the two types of vertical roots, and in the first foot portions of those roots and the lateral roots if the few extreme variations are not allowed to bias the picture.

5. The percentages of reducing sugars, total sugars, and starch-dextrin fraction in 7 portions of the bindweed root system at 14 periods of sampling —April 1 to November 1, inclusive—were determined and reported.

6. A composite fraction, consisting of total sugars and the starch-dextrin fraction, was computed and reported. It is designated the readily available carbohydrate fraction.

7. All of the carbohydrate fractions, except the reducing sugar fraction, reached low points in all of the root portions during the interval of April 15 to May 15. In many instances this was the low point of the season for that fraction in that portion.

8. The total sugars attained a seasonal maximum the first of November in the lateral roots and the first foot portion of the two types of vertical roots. In the other portions of the root system there was a tendency to attain a high point on or before July 15 and a maximum later in the season but prior to November 1.

9. The starch-dextrin fraction attained a maximum in the permanent lateral roots and in the first foot portion of the two types of vertical roots on October 1, and in the interval of August 15 to September 1 in the third foot portion of the vertical roots. The second foot portion of the vertical roots reached high levels on August 15 and October 1.

10. The readily available carbohydrate fraction followed the trend of the starch-dextrin fraction closely, attaining a maximum in the permanent lateral roots and the first foot portion of the two types of vertical roots on October 1, and in the second and third foot portions of the two types of vertical roots in the interval of August 15 to September 1, except in the second foot of the primary vertical root which attained seasonal high points on August 15 and October 1.

11. The total nitrogen fraction and the total readily available carbohydrate fraction are considered more reliable indices of the reserves of the plant than any of their component parts, the readily available carbohydrate fraction being the more reliable of the two.

12. The differences between comparable portions of the vertical roots were treated statistically. The t test was used to determine probability. Certain of the differences were statistically significant, some to a high degree. The effect of control procedures on these differences is not known.

13. All results were also computed and reported on a basis of the actual amount in grams per hundred lineal feet of each of the reserve food fractions in each of the root portions.

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